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(19) (CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) Snowmobile Floatation System

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(71) Same as inventor

(57) 7 Claims

Notice: This application is as filed and may therefore contain an incomplete specification.

SUMMARY OF THE INVENTION

In one embodiment there is provided a snowmobile having a body with a front end, a middle portion and a back end, top and bottom, and a flotation system integral thereto, said flotation system comprising:

a plurality of inflatable flotation means mounted at spaced locations on said snowmobile including two inflatable flotation means on opposed sides interior and underneath of said middle portion and one inflatable flotation means located interior and underneath of said front end; a compressed gas source; conduit means connecting said gas source with each of said inflatable flotation means; actuating means for releasing said compressed gas from said source to inflate said inflatable flotation means, said actuating means being integral with said source; each of said flotation means further comprising an inflatable envelope fluidly connected to said fluid passageway means; said envelope being collapsed prior to inflation, interiorly, underneath and within said body of said snowmobile enclosed by a sealed waterproof cover, continuous in nature.

In another embodiment the flotation system described herein further comprising an integral puncture actuator and cannister system with conduit means connected to said cannister..

In yet another embodiment the flotation system described herein further comprises said actuator including a manually actuable handle fluidly connected to a puncturing means.

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SPECIFICATION

1.0 Introduction

Snowmobiling is a popular winter sport in Ontario. Unfortunately, there a number of snowmobiling accidents that occur each year. A significant proportion of these accidents are water-related, and arise from snowmobiles breaking through thin ice, or encountering open water conditions while travelling on lakes and rivers.

A Snowmobile Floatation System has been proposed to permit the snowmobile and riders to stay afloat on the surface of the water after an accident has occured. This report examines the accident problem in Ontario, and presents a possible design solution for such a floatation system.

2.0 Water-Related Snowmobile Accidents in Ontario

2.1 Snowmobiling as a Recreational Sport in Ontario

Snowmobiling continues to be a popular winter recreational sport for people in Ontario. Statistics from the Ontario Ministry of Transportation [1] indicate that, for the years 1986 to 1992, an average of about 21,500 new snowmobiles per year were registered in the province. To service this growth, Ontario boasts one of the most extensive and well organized snowmobile club and trail systems in the world. Apart from being an enjoyable winter pastime for Ontarians, the sport of snowmobiling has proven to provide a significant economic base to the central and northern regions of the province. To further stimulate growth in the snowmobiling tourism industry, the Ontario Government has recently provided approximately 14 million dollars in funding to expand and upgrade the existing trail network.

Due to the abundance of lakes and rivers in Ontario, much snowmobiling is done on or near ice. Under proper conditions, ice travel by snowmobile provides a means to enjoy and explore parts of the province that are otherwise difficult to reach during winter. However, a serious problem results when snowmobilers attempt to travel on ice that is thin or of poor quality. Each winter in Ontario, there are a number of snowmobile accidents that invlove breaking through thin ice. The typical result of these accidents is death due to drowning, exposure, or catastrophic injury.

2.2 Accident Statistics

Limited statistics on water-related snowmobile accidents are available for two main groups: fatalities and catastrophic injuries. Ice breakthroughs that do not result in one of these effects generally go unreported and are therfore very difficult to quantify. The following data has been compiled from several different sources

The most recent data available is for the snowmobiling seasons of 1992/93 and 1993 /94. The information was provided by the Ontario Provincial Police, Traffic and Marine Branch, Orillia, Ontario.

In the season of 1992/93, there were 30 reported snowmobile accidents, of which, 17 were alcohol-related and 7 were water-related. ~~There were~~ 35 people were killed in

these accidents. In the season of 1993/94, there were 23 reported accidents, of which 11 were alcohol-related and 5 were water-related. These accidents resulted in 23 fatalities. . The dates, locations and circumstances of the water-related fatalities are summarized in Tables 2.1 and 2.2. The number of fatalities involved in each incident was unavailable.

Investigating Police	Accident Date	Accident Circumstances
N.E. Patrol, South Porcupine	18 Dec. 1992	- thin ice, drowned
OPP, Espanola Detachment	23 Dec. 1992	- broke thru thin ice, drowned
OPP, Haileybury Detach.	24 Dec. 1992	- broke thru thin ice, drowned
OPP, Brockville Detachment	18 Jan. 1993	- through ice, drowned
OPP, Huntsville Detachment	23 Jan. 1993	- hit open water, downed
OPP, Midland Detachment	24 Jan. 1993	- drove on open water, drowned
OPP, Parry Sound Detach.	29 Jan. 1993	- broke thru thin ice, drowned

Table 2.1: 1992/93 Reported Water-Related Accidents

Investigating Police	Accident Date	Accident Circumstances
N.W. Patrol, Souix Lookout	12 Nov. 1993	- open water, drowned
OPP, Kenora Detachment	20 Nov. 1993	- unsafe ice, drowned
OPP, Orillia Detachment	26 Dec. 1993	- travelling on thin ice, drowned
N.W. Patrol	30 Dec. 1993	- thin ice, drowned
OPP, Shubaque Detachment	23 April 1994	- hit open water, drowned

Table 2.2: 1993/94 Reported Water-Related Accidents

The Royal Life Saving Society Canada, Ontario Branch, has compiled data from the Chief Coroner's Office, of the number of water-related accidental deaths per year for various recreational activities in Ontario. Figure 2.3 [2] shows that, for the years 1987-1992, there was an average of 14 water-related deaths per year due to snowmobiling. This puts snowmobiling in the top 7 recreational activities for Ontario water-related accidental deaths. On a national level, there was an average of 27 accidental water-related fatalities per year in Canada from 1990-92 due to snowmobiling on thin ice [3].

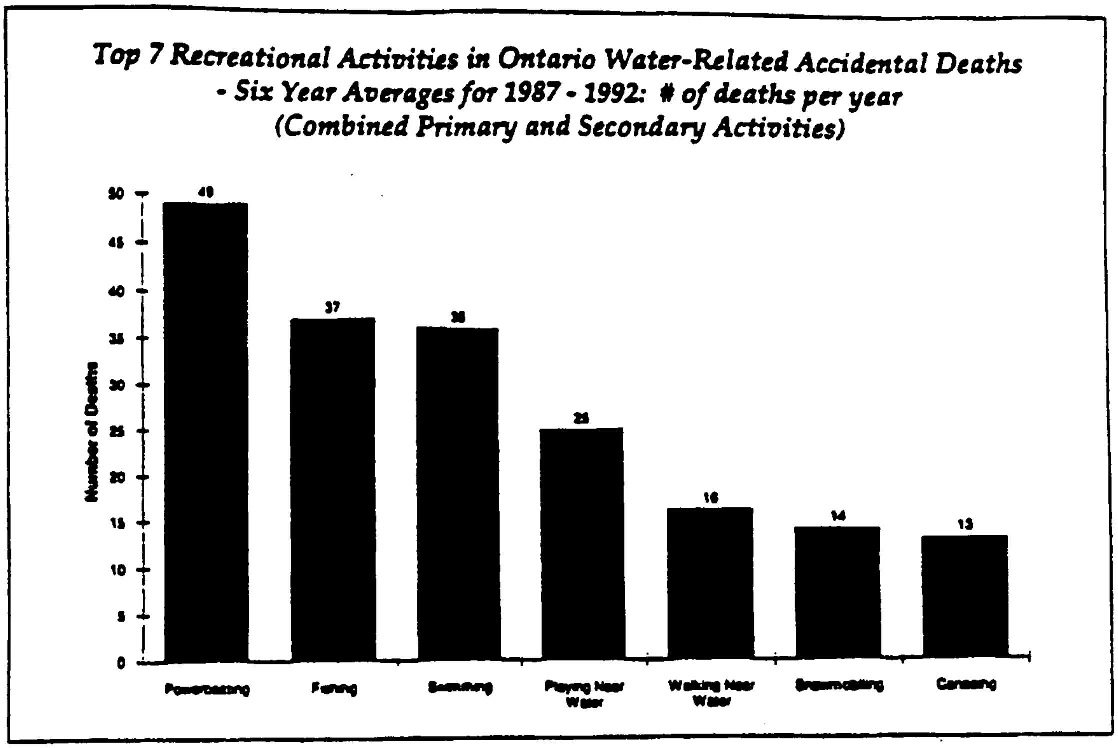

Figure 2.3: Avg # of Water-Related Snowmobiling Deaths Per Year 1987-92

Aside from deaths, many non-fatal catastrophic water-related injuries occur each year due to snowmobiling ice breakthroughs. The Think First Foundation of Canada, in their "Ontario Sports Recreational Injuries Survey 1992", reports that there were 10 water-related injuries due to snowmobiling in 1989, and 5 in 1992. Figure 2.4 [2] shows that water-related injuries arising from snowmobiling accidents are comparable in number to those of boating, for the years examined. Most of the snowmobiling injuries are a result of hypothermia induced from being exposed to very low temperature waters.

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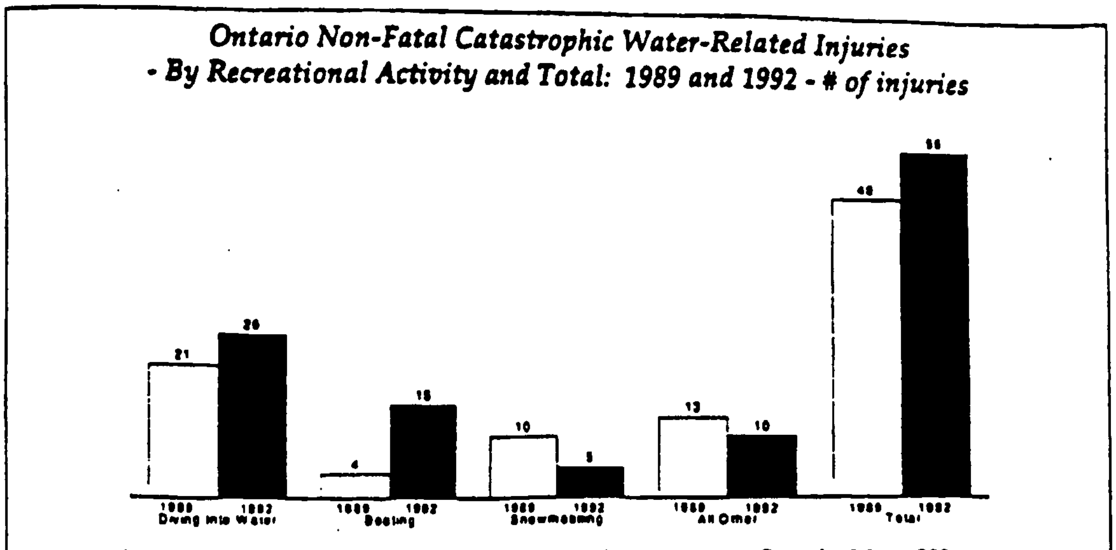

Source: "Ontario Sports Recreational Injuries Survey 1992", SportSmart Canada, May 1993

Figure 2.4: Non-Fatal Catastrophic Water Related Injuries From Snowmobiling

2.3 Typical Accident Conditions and Occurances

Snowmobile ice breakthroughs occur all throughout the winter months, but most seem to occur early in the season. This can be partly attributed to the relatively non-uniform and unpredictable ice conditions associated with the freezing of lakes and rivers at the start of the season. Often a body of water will develop a thin layer of ice, and then receive a significant layer of snow on top. This acts as an insulator which impedes further thickening of the ice, even though ambient temperatures may be below the freezing point. Another reason for the high incidence of accidents early in the season, is the fact that many snowmobilers are so eager to get their first ride of the season, that they fail to recognize the possibility of dangerous ice conditions.

The typical areas for thin ice snowmobile accidents to occur, are areas of currents, or otherwise non-stationary waters. It is these areas where ice may not form at all, or may form to depth that is insufficient in strength to support the weight of a snowmobile. Rivers are the most dangerous to travel on. The water is usually always moving underneath and shifting currents can make for rapid fluctuations in ice conditions. The areas of lakes that are most dangerous are narrows, such as entrances

to bays or underneath bridges, shoals, or locations where rivers empty into or flow out of lakes.

Most ice accidents occur at night ~~when the~~ when the visibility distance is limited to that of the snowmobile's headlight. With the relatively high cruising speeds afforded by modern snowmobiles, there is usually not enough time to react to avoid danger once detected. Travelling at night also can lead operators into unfamiliar territory due to the difficulty in distunguishing landmarks.

According to the Ontario Provincial Police and the Royal Life Saving Society of Canada [3], alcohol is involved in approximately 40 -50% of all investigated snowmobile accidents. The effect of impairment on the judgement and reaction time of an operator significantly reduces his/her ability to avoid dangerous ice conditions.

When snowmobiles break through thin ice, they usually do so at relatively slow speeds. Travelling at very high speeds can actually allow a snowmobile to continue indefinitely, even on very thin ice. However, many regions of thin ice or open water are surrounded by thick, heavy snow or slush. This has the effect of slowing the snowmobile down significantly due to the tremendous drag forces imposed by this type of surface condition. Upon breaking through, the snowmobile is usually sinks straight down, with a relatively flat attitude, and is completely submerged in about 2-3 seconds.

When a snowmobile operator or passenger of a sinking snowmobile contacts the freezing water, they typically have between 5 and 10 seconds to get out before being overcome by the paralyzing effect of the tremendous body heat loss. After this point, it is virtually impossible for the person be able to stay afloat to prevent from drowning. The amount of water that can be absorbed by a typical snowmobile suit and set of boots is enough to increase the rider's effective weight to the point where it is very difficult to pull himself/herself up from the water onto the ice surface without assistance. Even if the person does manage to get out of the water, he/she has very little time to obtain warmth before succumbing to exposure.

2.4 Prevention of Water-Related Snowmobile Accidents

Water-related snowmobile accidents happen frequently enough that they are regarded as a very real and significant hazard in the sport. The Ontario Federation of Snowmobile Clubs (O.F.S.C) recognizes their significance and is currently taking steps to fully assess the magnitude and effect of the problem. The O.F.S.C has recently commissioned Tandem International Inc. management consultants, to perform a detailed, 5-year analysis of fatalities resulting from water-related snowmobile accidents in the province. The report is scheduled to be completed by mid February, 1995. Snowmobile accidents of all types only serve to detract from the sport, hence, it is of the Federation's best interest to understand the problems, so that it may educate snowmobilers on how to avoid incidents and make the sport safer.

Other agencies are also interested in preventing water-related snowmobile accidents. The Royal Life Saving Society Canada (RLSSC), compiles accident statistics yearly in the form of provincial and national reports to help educate society about drownings and water-related accidents. It is the Canadian authority in water survival education and life guarding.

The Think First Foundation of Canada (Formerly SportSmart Canada) of the Toronto Hospital, Western Division, compiles data on catastrophic and trauma injuries as a result of water-related snowmobile accidents. The organization publishes a report every three years summarizing injuries called the "Ontario Sports Recreational Injuries Survey". Another agency, the Safety Resource Centre, Toronto, serves as an information source for the public on safety and accident prevention. The Centre offers literature and video information on snowmobile safety. The Ontario Provincial Police have special units such as the Traffic and Marine Branch based in Orillia, Ontario, that serve to monitor accidents in the province, as well as offering certain courses on safe snowmobile operation. The OPP also perform snowmobile patrolled RIDE programs in parts of the trail networks, in an attempt to reduce the number of impaired snowmobiliers.

A committee has been formed in province called the Ontario Snowmobile Safety Committee, which has as its mandate the advancement of the sport's safety level. The committee consists primarily of representatives from the aforementioned agencies. The committee meets monthly to discuss means of accident prevention.

Aside from the current efforts being undertaken by the various organizations in Ontario to help prevent snowmobile accidents, legislation by the provincial government may also help reduce the casualties each year. Presently in Ontario, there is no requirement of an operator of a snowmobile to have a license. The snowmobile itself must be licensed, but there is no formal way of assessing the competence of a snowmobiler in the safe operation of his or her machine. Imposing a license of this sort may serve to more fully educate and train operators on how to assess and/or avoid dangerous ice conditions, and what to do in order to increase the chances of survival in the event of an accident. Other legislation possibilities include: providing regulations for mandatory safety equipment such as buoyant snowmobile suits, lifejackets, etc., lake travel safety regulations, and the provision of more police instituted RIDE programs, to reduce alcohol consumption on the trails.

In yet another embodiment of the flotation system said actuator further comprises an electrically operated explosive charge for automatic operation of said puncturing means.

In yet another embodiment of the flotation system further comprising a flotation responsive switch mounted in a strategic location proximate the bottom immediately adjacent the exhaust pipe exit.

In yet another embodiment of the flotation system said inflatable envelope further comprises material substantially resistant to ice puncture and the like.

In yet another embodiment of the flotation system said system is used for saving lives in the event of said snowmobile falling through ice.

Further and other objects of the invention will become apparent to those skilled in the art when considering the specification. As many changes can be made to the preferred embodiments of the invention without departing from the scope of the invention, it is intended that all material contained herein be interpreted as illustrative of the invention and not in a limiting sense.

3.0 A Snowmobile Flotation System as an Aid During Water-Related Snowmobile Accidents

The seriousness of water-related snowmobile accidents in Ontario has been presented, along with some of the means that either are, or could be undertaken to reduce the occurrences of the problem. Another proposal, while not preventing the accidents from happening, may serve to help save the lives of those who are involved in snowmobile accidents of this particular type.

The proposal is a Snowmobile Flotation System. The system would provide means for the snowmobile and riders to remain afloat after either breaking through thin ice or encountering open water conditions while traveling on frozen lakes and rivers. The system would prevent the riders from coming in contact with cold waters, thus preventing drowning or exposure, and also would prevent the loss of the snowmobile due to sinking.

The remainder of this report is dedicated to examining possible design solutions and the technical feasibility of such a system.

4.0 Design Criteria and Constraints

In order for the Snowmobile Flotation System to be an effective aid during water-related snowmobile accidents, it must conform to a set of distinct design criteria and constraints that dictate how the system must perform, and under what limits it must perform.

The Snowmobile Floatation System shall be automatically activated, and must be fully operational within 5 seconds of the commencement of sinking. Provisions must exist for manual activation as a backup for the automatic activation. The system must permit the snowmobile and two riders to remain afloat on the surface of the water for a minimum period of 3 hours after activation The system shall at no time allow the passengers to be exposed to water above the knee level, (as measured in the normal seated operating position), or above the snowmobile seat level ,whichever is lower. The Snowmobile Floatation System shall be fully operational under ambient temperatures as low as -40 °C.

The Snowmobile Floatation System shall be adaptable to meet the requirements of currently manufactured snowmobiles, and shall not require extensive modifications to the existing vehicle superstructure. All component and performance specifications shall be such that they meet a minimum factor of safety of 1.2 above the extreme anticipated service conditions. The system shall in no way inhibit the safe operation of the snowmobile under normal snowmobiling conditions.

5.0 Possible Design Solutions

A number of possible design solutions were analyzed to determine their suitability for incorporation in the Snowmobile Floatation System. The possibilities are discussed in the following sections.

5.1 Floatation Methods

Two methods of floatation were considered for the system: that of fixed shape floats, and that of flexible, inflatable floats or floatation bags. Preliminary calculations indicated that the volume of water that was required to be displaced in order to provide floatation for the snowmobile and riders was such that it would make fixed shape floats impractical for regular snowmobile operation. Inflatable floats or would allow for compact storage within the existing snowmobile structure until their requirement, at which point they could be inflated. This method of floatation would also prove to be reasonably light when compared to a rigid float system. A drawback to inflatable floats would be their susceptibility to tears and leakage. However, this potential problem could be addressed through proper choice of materials.

5.2 Inflation Means

For the inflatable float design, a means of providing rapid inflation to the floatation bags is required. Two existing technologies where investigated for accomplishing this.

Compressed gas inflation canisters are routinely used for the inflation of life rafts, personal floatation devices (PFD's) and other marine safety equipment. The gas typically used is Carbon Dioxide (CO_2), and is usually mixed with a small portion Nitrogen gas (N_2) to help maintain flow rates under cold temperature conditions. Inflation times for compressed gas inflator systems are in the order of seconds to 10's of seconds depending on system sizes. Compressed gas inflator technology has been in common use in North America since 1930, and hence benefits from a wide selection of standard components.

Pyrotechnic gas inflator systems have recently come into common use for automotive air bag applications in the past 5 years. The gas is usually evolved from a vigorous chemical reaction between Sodium Azide and Oxygen. Inflation times are on the order

of hundredth's of a second for nominal automotive air bag volumes (less that 100 litres). In spite of the pyrotechnic inflator's rapid inflation rate, it has the disadvantage of being very expensive to replace once used. Also, because of the relative newness of this technology, component availability is limited and expensive. There also remain safety concerns with this technology in the areas of accidental ignition and high gas temperatures.

In comparing these two methods of inflation for the Snowmobile Floatation System, the major factors that were considered were the size requirements and the method of activation. A compressed gas system would easily lend it self to both manual and automatic (electric) activation, due to the nature of existing valve components. A pyrotechnic inflator is usually ignited electrically, and hence it may prove difficult to incorporate a manual release. It would however, require less storage space on the snowmobile and would not require the routing of the gas distribution hoses required for a compressed gas system.

5.3 Float Location

Float locations were considered based available space for stowage, and the ability of the location to provide buoyancy stability for the snowmobile system in the water.

The first layout considered incorporated a floatation bag in the rear seat storage compartment, to support the rear of the snowmobile. Along with this would be two bags positioned on each side of the lower belly pan immediately above the rear edges of the skis. This configuration would provide stability from the three point support, and should fit in within the space restrictions of the average snowmobile. A potential drawback of this layout is the relatively high mounting position of the rear bag. This may permit the rear of the snowmobile to sit too low in the water, whereby allowing the riders to get wet.

The second layout examined, consisted of two tube-shaped floats fixed under each of the snowmobile's footrests. These tubes would support the rear portion of the system weight, as well as provide lateral stability due to the width of the tube spacing. A third float would be affixed to the front of the belly pan, under the leading edge of the cowling. This float would take the front portion of the weight. This arrangement would have the advantage of having the floats positioned low enough to keep the

snowmobile sufficiently above the water level. A potential drawback of having the two rear floats affixed to the underside of the footrests, is their susceptibility to damage when traversing rough terrain. However, protective sheaths could be fashioned from a sufficiently durable material to resist damage.

5.4 Automatic Release Mechanism

For the use of inflatable floats, an automatic release mechanism is required to initiate bag deployment in the event of an ice break-through. The release mechanism must act on a signal from an accident sensor (discussed separately) to trigger the inflation process. The design of the automatic release mechanism will depend on whether it is used for a compressed gas inflator or a pyrotechnic type inflator.

A automatic release mechanism for a compressed gas inflator could consist of an electric solenoid connected to the squib wire on the compressed gas canister. The squib wire is the wire that is pulled to initiate gas flow on standard life raft systems. The solenoid could be powered by a 12 V battery common to many snowmobiles with electric start. Upon receiving the signal from the accident sensor, the solenoid would energize, whereby pulling the squib wire to start the inflation process.

An automatic release system for a pyrotechnic type inflator could consist of a battery that would to supply a voltage to the inflator ignitor when given a signal from the accident sensor.

5.5 Manual Backup Release Mechanism

In the event of a snowmobile power system failure or dysfunction of the automatic release mechanism, a manual backup release mechanism must be available to allow the operator to initiate inflation. The design of the manual backup release mechanism will depend on whether it is used for a compressed gas inflator or a pyrotechnic type inflator.

A manual backup release mechanism for a compressed gas inflator could consist of an actuator cable, with one end connected to the canister squib wire, and the other end connected to a release lever on the snowmobile instrument panel. Inflation would be initiated by the operator pulling the release lever.

A manual backup release mechanism for a pyrotechnic type inflator would be somewhat more difficult to develop than for a compressed gas inflator. Almost all currently available automotive inflators use an electrically operated igniter. To use a system of this type, the manual release mechanism would have to generate a voltage suitable to power the igniter. Recently however, some pyrotechnic inflator manufacturers have developed mechanically actuated systems. These may prove to be useful for this application.

5.6 Accident Sensor

An accident sensor is required to accurately detect when the snowmobile is sinking. The electrical signal output from the sensor will control the operation of the automatic release mechanism. The sensor should not accidentally initiate inflation under normal riding conditions.

A sensor that detects the presence of water through moisture or temperature measurement is a possibility. Difficulty may be encountered with the reliability of a sensor such as this however. Snowmobiling is sometimes performed under wet or slushy conditions. A sensor or this type would have to differentiate between these conditions and an actual sinking.

Another type of sensor that may prove effective is a float type sensor. The action would be similar to a carburetor float mechanism. Water taken in at the beginning of an ice accident would cause the float to rise and actuate a switch. The float would have to be designed to remain unaffected by the inertial loads encountered during normal riding. It would also have to be strategically located to avoid being frozen by snow and ice.

6.0 Description of the Proposed Design Solution

Each of the possible design solutions were considered for their feasibility and practicality for use on a typical production snowmobile. Preliminary calculations were performed and estimations were made to determine which solutions would be most effective for cost reduction, weight minimization, ease of fabrication, reliability, and performance. The chosen solutions presented are tentative only, and may change as the project advances through the construction and testing stages.

6.1 Floatation

It was decided to use inflatable floats for the Snowmobile Floatation System as opposed to rigid type floats because of the small storage space required. Rigid floats would be two bulky to be of any practical value on a snowmobile.

The floatation bags will be fabricated from neoprene and hypalon coated nylon. This material is used commonly in the manufacture of high quality life rafts and will provide excellent resistance to puncture, tears, leakage and degradation due to aging. The material cold vulcanizable, which makes it suitable for hand gluing.

The rear floatation bags will be shaped as tubes when fully inflated. Prior to inflation, they will be folded and housed in sealed deployment strips to protect them until needed. The deployment strips will be mounted on the snowmobile track tunnel, one under each footrest. Figure 6.1 shows one of the rear floatation tubes, with the deployment strip and its mounting position.

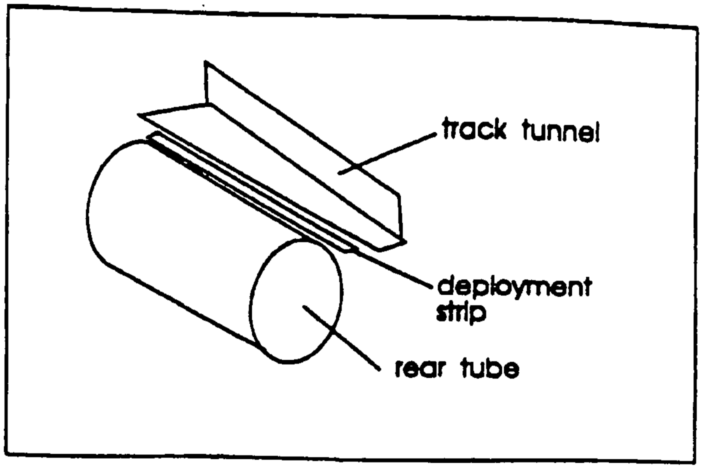

Figure 6.1: Rear Floatation Tube

The front floatation bag will be roughly rectangular in shape and will be housed in a deployment container affixed to the inside front of the snowmobile belly pan. Upon inflation, the bag will deploy frontwards out over the skis to provide floatation to the front end of the snowmobile.

6.2 I 'lation System

The compressed gas inflator was chosen over the pyrotechnic type because of it's ruggedness, cost effectiveness and availability. A carbon dioxide and nitrogen gas mixture will be used to maintain suitable inflation times under cold temperature conditions. A compressed gas canister will be selected to house the required mass of CO_2 gas at a pressure of approximately 12.4 MPa. High pressure hoses will be used to connect the gas canister to the floatation bags.

6.3 Release Mechanisms

A solenoid operated, automatic release mechanism will be used as described in Section 5.4. The power will be derived from a 12 V snowmobile battery that will be charged by the snowmobile engine magneto.

A cable operated , manual backup release mechanism will be provided to allow the operator to initiate inflation by pulling lever or cord on the front console of the snowmobile.

6.4 Accident Sensor

The chosen design of the release sensor is that of the float type. It is felt that this is the most promising method of detecting a sinking snowmobile. In order to prevent the sensor from being fouled by snow and ice, it is proposed to mount it just inside of the lower belly pan, close to the exhaust pipe exit hole in the cowling. This hole in the cowling is one of the first areas that water will enter when the snowmobile starts to sink. The heat from the exhaust pipe should prevent any buildup of ice in the sensor.

The sensor will likely consist of a light weight plastic or cork float mounted on a lever of a micro switch. Lightweight springs will provide forces against the float to prevent activation of the switch under inertial loading, but will be overcome when the float is surrounded by water due to the buoyant forces.

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7.0 Test Snowmobile For System Prototype

The design of the Snowmobile Floatation System is to be based on meeting the requirements of typical modern snowmobile. A test snowmobile has been selected that suitably represents the style and layout of currently available machines. The model is a 1988 Arctic Cat El Tigre 5000.

The Arctic Cat snowmobile has a mass of approximately 230 kg. and has the seating space for 2 riders. It is powered by a 49 kW, 2-cycle, liquid cooled engine. The front ski stance is approximately 94 cm and the track width is 40 cm. Front suspension is provided by a coil-over-shock A-arm system, yielding approximately 15 cm of vertical travel. The rear suspension is of the slide rail type and provides approximately 17 cm of travel.

This machine will be used for testing the prototype Snowmobile Floatation System. Hence, it will be used for determining design parameters such as weight, centres of gravity, and component packaging space.

8.0 Calculation of System Parameters

8.1 Determination of Snowmobile Centre of Gravity

The centre of gravity of the test snowmobile for the prototype snowmobile floatation system is required to properly size and locate the floatation bags for buoyancy stability. The centre of gravity location was determined by measurement in longitudinal, transverse and vertical directions, under three loading cases. Load case 1 was the snowmobile with no rider weight, load case 2 was the snowmobile with an operator, and load case 3 was the snowmobile with an operator and a passenger. The three load cases are intended to yield the centre of gravity locations of the snowmobile system under typical operating conditions.

8.1.1 Longitudinal and Transverse Direction Measurement

The location of the snowmobile centre of gravity in the longitudinal and transverse directions was measured using weight scales placed at three locations under the chassis. Two scales were used at the front, placed directly under the suspension upright of each ski. A third scale was placed at the rear of the snowmobile, centred under the grab bar behind the seat cushion. The distance between the scales from front to back was measured to be 210.8 cm.

Upon measurement of the three load cases, it was observed that the readings of the front two scales were nearly equal to one another. This suggested that the centre of gravity in the transverse direction was located approximately along the center line of the snowmobile, which is expected because of geometric symmetry about this line.

In load case 2, the operator mass used was 87 kg. In load case 3, the operator mass used was 87 kg, and the passenger mass was 57 kg. The results of the measurements are presented in Table 8.1 . The readings of the front scales are combined in each load case.

Load Case	Front Scale Weight (N)	Rear Scale Weight (N)	Total Weight (N)
snowmobile only	1566	757	2323
snowmobile + operator	1976	1202	3178
snowmobile + operator + passenger	2083	1606	3689

Table 8.1 : Weight Distributions

The measured weights and the distance between the scales can be used to find the location of the centre of gravity for each load case through equilibrium analysis. The centre of gravity location is measured relative to the longitudinal location of the front weight scales (the position of the front suspension upright). By summing moments about this point, the location of the centre of gravity is found;

$$x_{CG} = \frac{W_{RS} \times D}{W_T} \tag{1}$$

where: x_{CG} is the distance of the longitudinal centre of gravity behind the front suspension upright

W_{RS} is the weight measured by the rear scale

D is the distance between the front and rear scales

W_T is the total measured weight of the three scales

The results of the calculations using equation(1) are summarized in Table 8.2. Sample Calculations are provided in Appendix B.

Load Case	x_{CG} (cm)
snowmobile only	68.7
snowmobile + operator	79.8
snowmobile + operator + rider	91.7

Table 8.2: Location of Longitudinal Centres of Gravity

8.1.2 Vertical Direction Measurement

The location of the centre of gravity of the snowmobile in the vertical direction was measured by swinging the snowmobile as a pendulum and measuring the period of swing about two different pivot points. This method was chosen because of its ability to easily accommodate the riders in the measurement process.

The period of a physical pendulum for small angles of swing is given by [4];

$$T = 2\pi\sqrt{\frac{I}{Mgd}} \tag{2}$$

where:
- T is the period of swing
- I is the rotational inertia of the pendulum about an axis through the pivot
- M is the mass of the pendulum
- g is the acceleration of gravity
- d is the distance from the pivot to the centre of gravity of the pendulum

By using the parallel axis theorem, eqn.(1) may be rearranged and solved for the rotational inertia of the pendulum about its centre of gravity I_G ;

$$I_G = \frac{MT^2gd}{4\pi^2} - Md^2 \tag{3}$$

If pendulum is swung about two different pivot points, then two equations can be written for I_G and equated to solve for the distance from one of the pivots to the centre of gravity of the pendulum;

$$d_{1,P} = \frac{4\pi^2 \Delta d^2 - T_2^2 g \Delta d}{-8\pi^2 \Delta d - (T_1^2 - T_2^2) g} \tag{4}$$

where; $d_{1,P}$ is the distance from the lower pivot to the centre of gravity of the pendulum

Δd is the distance between the pivots

T_1 is the period of swing about the lower pivot

T_2 is the period of swing about the upper pivot

A complete derivation of eqn.(4) is given in Appendix A. Refer to Figure 8.1 for a diagram of the physical pendulum swung about two different pivot points.

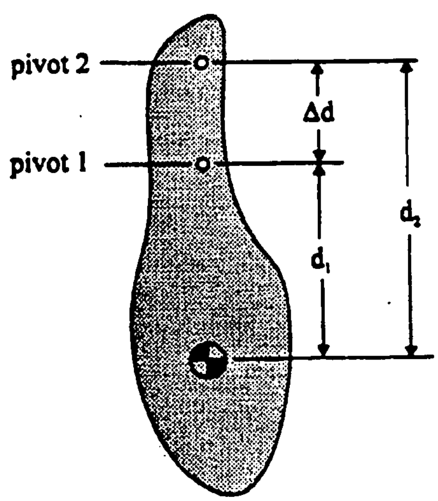

Figure 8.1: Pivot and C of G locations of a Physical Pendulum

A cradle system was constructed to facilitate the swinging of the test snowmobile as a physical pendulum. A support platform on which to place the snowmobile

was fabricated from a 4'x8' sheet of plywood, 0.5" thick. Two 2"x4" reinforcement ribs were affixed transversely to either end. A pivot beam formed from 3" angle steel with welded pivot eyelets was secured overhead. 0.25" dia. rope was tied from each corner of the platform to the one of the pivot eyelets to form a cradle. Slip knots were incorporated in each rope length to allow pivot length adjustment and platform leveling. The snowmobile was placed along the long axis of the platform and centred. A leveling procedure was carried out at each of the two pivot lengths to ensure equal weight distribution. Refer to Figure 8.2 for a schematic of the cradle system.

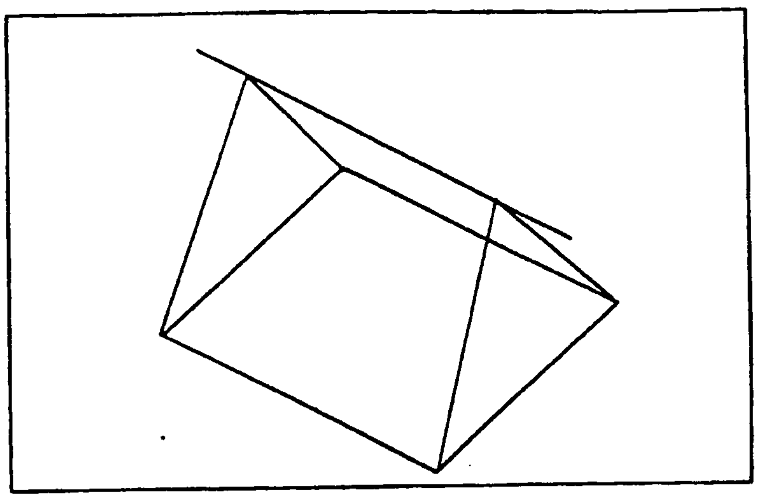

Figure 8.2: Cradle System

The snowmobile and cradle system was swung at two different pivot heights under the same three loading conditions as in the longitudinal and transverse direction measurement. The operator and passenger masses were 68 and 73 kg respectively. The height of pivot 1 was 232.4 cm, measured from the top surface of the platform to the pivot axis. The height of pivot 2 was 285.8 cm, measured in the same manner. Oscillation over an arc of approximately 5° was initiated by hand. The time for 50 cycles was measured with a stopwatch and recorded for each case. This time was subsequently divided by 50 to obtain an accurate value for the period of swing. The results of the test are summarized in Table 8.3

Load Case	Pivot 1		Pivot 2	
	Time for 50 Cycles (s)	Period of Swing (s)	Time for 50 Cycles (s)	Period of Swing (s)
Snowmobile only	143.6	2.872	161.9	3.238
Snowmoblie + Operator	141.8	2.836	160.0	3.200
Snowmobile + Operator + Passenger	141.0	2.820	159.0	3.180

Table 8.3: Results of Pendulum Swing Test

The measured periods of swing were then used with equation (4) to calculate the distance of the pendulum centre of gravity below pivot 1, for each load case. The pendulum is taken to be comprised of the snowmobile system (snowmobile plus any riders) and the cradle system. In order to find the distance of the centre of gravity of the snowmobile system below pivot 1, the effect of the cradle must be subtracted from the pendulum result. The distances of the centres of gravity of the pendulum, snowmobile system, and cradle system below pivot 1 are related as follows:

$$W_P d_{1,P} = W_S d_{1,S} + W_C d_{1,C} \qquad (5)$$

where: W_P is the weight of the pendulum

$d_{1,P}$ is the distance of the centre of gravity of the pendulum below pivot 1

W_S is the weight of snowmobile system

$d_{1,S}$ is the distance of the centre of gravity of the snowmobile system below pivot 1

W_C is the weight of cradle system

$d_{1,C}$ is the distance of the centre of gravity of the cradle system below pivot 1

The cradle system weight was measured to be 290.4 N and was taken to have its centre of gravity located at the centre of the plywood platform (the mass of the thin ropes were considered to be negligible). The distance of the centre of the plywood platform from pivot 1 was measured to be 233.0 cm.

Using the calculated centre of gravity of the pendulum, the centre of gravity was determined for each snowmobile system by rearranging and solving equation (5). This distance was then subtracted from the distance of the platform surface below pivot 1 (232.4 cm), to give the height of the centre of gravity of each snowmobile system above the platform (Z_{CG}). The results of the calculations are presented in Table 8.4. Sample calculations are provided in Appendix B.

Load Case	Z_{CG} (cm)
snowmobile only	18.7
snowmobile + operator	29.4
snowmobile + operator + rider	36.2

Table 8.4: Centre of Gravity Height

8.2 Buoyancy Calculations

According to the American Boat and Yacht Council [5], the maximum allowable floated weight of the Snowmobile Floatation System should be given by:

$$W = 0.75D \tag{6}$$

Where: W is the maximum floated weight [N]

D is equal to $9.79V$

and V is the floatation bag volume [L]

Eqn. (6) can be rearranged to solve for V. For a designed floated weight of 3770 Newtons (snowmobile and 2 riders), the required total floatation bag volume is calculated to be approximately 500 L. Refer to Appendix B for sample calculations.

8.3 Stability Calculations

8.3.1 Determination of Front and Rear Floatation Bag Volumes

This calculation was performed using the centre of gravity position for the single rider load case. This position represents the most common condition. By performing a moment balance about the centre or gravity of the snowmobile system, the front and rear bag volumes are related by:

$$\frac{V_R}{V_F} = \frac{F_R}{F_F} = \frac{d_F}{d_R} \tag{7}$$

where:
- V_R is the rear bag volume
- V_F is the front bag volume
- F_R is the rear bag buoyant force
- F_F is the front bag buoyant force
- d_R is the distance from the CofG to the rear bag centre of volume
- d_F is the distance from the CofG to the front bag centre of volume

The total volume of the front and rear bags is 500 L. From the above two relationships, the front and rear bag volumes were calculated to be 125 and 375 L respectively. Refer to sample calculations for these volumes in Appendix B. The Rear bag volume will be divided equally between two bags on either side of the snowmobile.

8.3.2 Calculation of Snowmobile Metacentric Height

The calculation of the snowmobile metacentric height is performed for the load case of the two riders, as this yields the highest vertical centre of gravity distance.

The cross section of the proposed floatation bags can be approximated by two circles, representing the rear floatation tubes, mounted on either side of the track tunnel, and a rectangular section, representing the shape of the front floatation bag mounted to the front of the snowmobile cowling. These cross sections and their approximate relative mounting positions in relation to the centre of gravity location on the snowmobile are, shown in Figure 8.3.

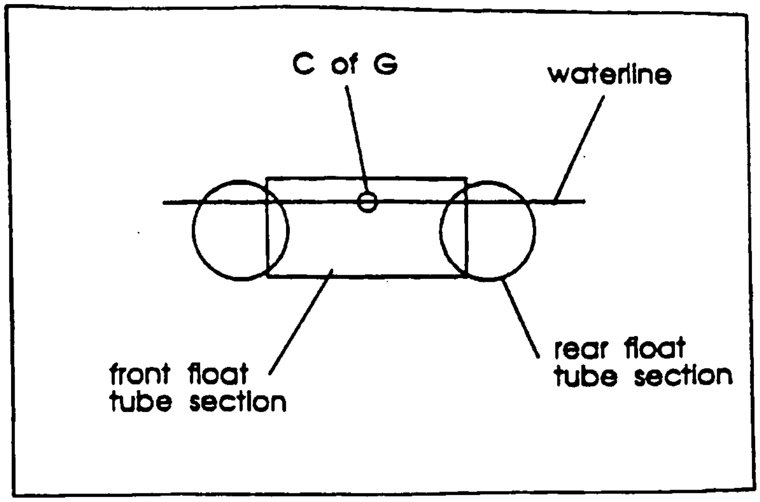

Figure 8.3: Floatation Bag Cross Section

The diameter of the rear tubes is approximately 50 cm and the centre distance between them is approximately 130 cm. The front bag profile is approximately 100 cm wide by 50 cm high. For simplification, the combined submerged cross section of the rear and front bags can be approximated as a rectangle of length 2L=178 cm and a height of H=38 cm. Refer to Figure 8.4.

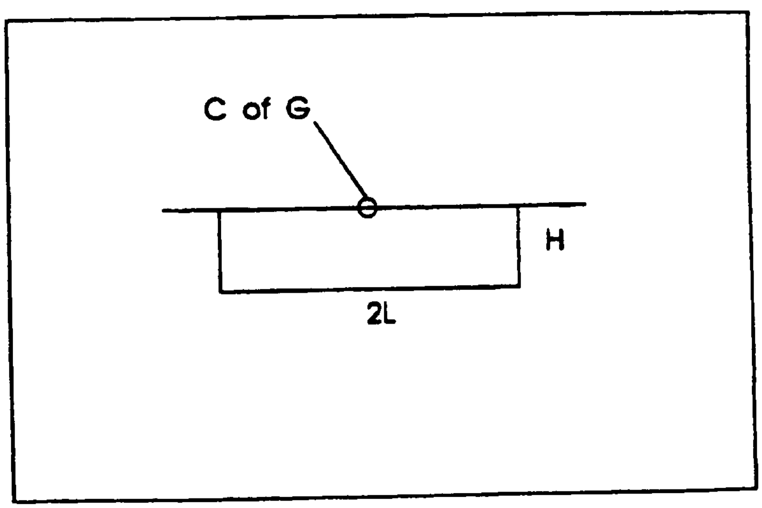

Figure 8.4: Simplified Floatation Bag Cross Section

By following White's procedure [6] for an approximate metacentric height calculation, the cross section is tilted by a small angle and the resulting shift in the centre of buoyancy (B') is determined. The resulting metacentric height is given by:

$$\overline{MB} = \frac{L^2}{3H} - \frac{H}{3} \tag{8}$$

Using this relationship and the dimensions L and H of the simplified rectangular cross section, the metacentric height of the snowmobile with 2 riders was found to be 50.5 cm. Because this is a positive quantity, the metacentre occurs above the centre of gravity, and the snowmobile system will be stable when floating in the water.

8.4 Calculation of Required Mass of CO_2 Gas

The required mass of CO_2 gas can be calculated by finding the specific volume of the gas under the extreme of the operation conditions, and dividing this into the total required volume of the floatation bags.

The extreme conditions expected will be an ambient temperature of -40° C and a bag pressure of 2 psig (13.8 KPa). From Raznjevic's thermodynamic property charts of CO_2 [7], the specific volume of CO_2 that corresponds to these conditions is about 420 L/kg. For a total floatation bag volume of 500 L, this corresponds to a required mass of CO_2 of 1.2 kg. Refer to the sample calculations in Appendix B.

8.5 Calculation of CO_2 Canister Volume

The canister will be sized to house 1.2 kg of CO_2 at a temperature of 30° C and a pressure of 1700 psig (12.4 MPa). From Raznjevic's thermodynamic property charts of CO_2 [7], the specific volume of CO_2 that corresponds to these conditions is about 1.5 L/kg. From this, a required canister volume of 1.8 L is calculated. Refer to the sample calculations presented in Appendix B.

8.6 Inflation Time Calculation

The inflation time of the floatation bags is predicted by performing a blowdown time calculation on the CO_2 canister. The process can be approximated by making a number of assumptions:

1) The stagnation pressure of the CO_2 in the canister is initially at 1700 psig (12.4 MPa) and decreases during the blowdown process.
2) The stagnation temperature of the CO_2 in the canister is initially 0° C (273 K) and remains constant during the blowdown process.
3) The CO_2 behaves as an ideal gas
4) The nozzle exit pressure is 18.7 psia (129 KPa)

The specific heat ratio of CO_2 is 1.30 [6]. For a sonic throat, the maximum mass flow rate for the gas will be given by [6]:

$$\dot{m}_{max} = 0.6673 \frac{P_0 A^*}{\sqrt{RT_0}} \tag{9}$$

For a nozzle of diameter 6.25 mm, the maximum mass flow rate will be 1.154 kg/s. Refer to the sample calculations presented in Appendix B. This represents the mass flow rate at the start of the blowdown process. As the stagnation pressure reduces due to the loss of CO_2 mass, the mass flow rate will decrease. To determine the blowdown time, a control volume analysis is performed on the canister to set up a differential equation relating pressure to time. A mass flow balance gives:

$$\frac{d}{dt}(\rho_0 V_{canister}) + \dot{m}_{exit} = 0 \tag{10}$$

where; $$\rho_0 = \frac{P_0}{RT_0}$$

by substituting the mass flow rate given by eqn (9) and separating,

$$\int \frac{dP_0}{P_0} = -\frac{0.6672 A^* \sqrt{RT_0}}{V_{canister}} \int dt \tag{11}$$

after integration,

$$P_0(t) = P_0(0)e^{\frac{0.6672A^*\sqrt{RT_0}}{V_{canister}}t} \qquad (12)$$

This equation can be solved for the time required to drop to a given pressure $P_0(t)$. By selecting this pressure to be the minimum pressure required for sonic flow (236.4 KPa), and using canister volume of 1.85 L, the blowdown time is determined to be 1.53 seconds. Refer to the sample calculations presented in Appendix B.

References

[1] MTO, "Ontario Road Safety Annual Report, 1992", **Ministry of Transportation. Ontario**, Section 6e pg 50.

[2] RLSSC, "The Ontario Drowning Report Sixth Edition",**The Royal Life Saving Society Canada, Ontario Branch**, pp 4,8, 1992.

[3] RLSSC, "The National Drowning Report Third Edition", **The Royal Life Saving Society Canada**, pp 2-3, 1992.

[4] Hibbeler, R.C.,Engineering Mechanics - Statics and Dynamics 5th ed., **Macmillan Publications**, pg 540, 1990.

[5] Hubbard. D, Complete Book of Inflatable Boats, **Western Marine Enterprises Inc.**, Ventura, California, pg 243, 1980.

[6] White, F.M., Fluid Mechanics, **McGraw-Hill Inc.**, Second Edition, 1986.

[7] Raznjevic, K, Handbook of Thermodynamic Tables and Charts, pp 382-383, 1978

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Appendix A

Derivation of Pendulum Formula

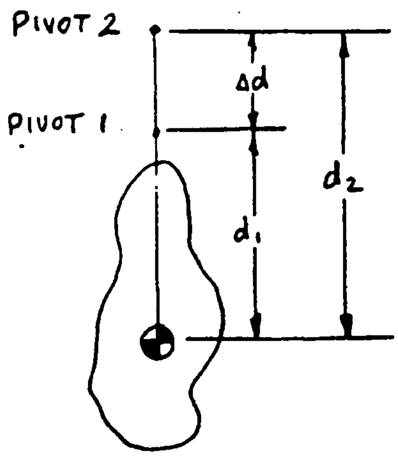
PERIOD OF A PHYSICAL PENDULUM :

$$T = 2\pi\sqrt{\frac{I}{Mgd}}$$

Eqn (2)
Sect 7.1

WHERE ; d IS THE DISTANCE FROM THE PIVOT PT. TO THE PENDULUM C of G
I IS THE ROTATIONAL INERTIA OF THE PENDULUM ABOUT AN AXIS THROUGH THE PIVOT
g IS THE GRAVITATIONAL CONSTANT
M IS THE MASS OF THE PENDULUM

FOR A PHYSICAL PENDULUM SWUNG ABOUT 2 DIFFERENT PIVOT POINTS :



REARRANGE Eqn. (2) IN TERMS OF I :

$$I = \frac{MT^2 g d}{4\pi^2}$$

FOR PIVOTS 1 & 2 :

$$I_1 = \frac{MT_1^2 g d_1}{4\pi^2} \quad (1) \qquad I_2 = \frac{MT_2^2 g d_2}{4\pi^2} \quad (2)$$

FROM PARALLEL AXIS THEOREM:

$$I_1 = I_G + Md_1^2 \rightarrow I_G = I_1 - Md_1^2$$
$$I_2 = I_G + Md_2^2 \rightarrow I_G = I_2 - Md_2^2$$

EQUATE I_G's

$$I_1 - Md_1^2 = I_2 - Md_2^2$$
$$I_2 = I_1 + M(d_2^2 - d_1^2) \quad (3)$$

SUBSTITUTE (1) & (2) IN (3)

$$\frac{MT_2^2 g d_2}{4\pi^2} = \frac{MT_1^2 g d_1}{4\pi^2} + M(d_2^2 - d_1^2)$$
$$T_2^2 g d_2 = T_1^2 g d_1 + 4\pi^2(d_2^2 - d_1^2)$$

ASIDE

$$d_2^2 - d_1^2 = (d_2 + d_1)(d_2 - d_1)$$
but $d_2 = d_1 + \Delta d$
$$(d_2 + d_1)(d_2 - d_1) = (d_1 + \Delta d + d_1)(d_1 + \Delta d - d_1)$$
$$= (2d_1 + \Delta d)\,\Delta d$$
$$d_2^2 - d_1^2 = 2d_1\Delta d + \Delta d^2$$

END OF ASIDE

$$T_2^2 g d_2 = T_1^2 g d_1 + 4\pi^2(2d_1\Delta d + \Delta d^2)$$

$$T_2^2 g d_1 + T_2^2 g \Delta d = T_1^2 g d_1 + 8\pi^2 d_1 \Delta d + 4\pi^2 \Delta d^2$$

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$$T_2^2 g\, d_1 - T_1^2 g\, d_1 - 8\pi^2 d_1 \Delta d = -T_2^2 g \Delta d + 4\pi^2 \Delta d^2$$

$$d_1 (T_2^2 g - T_1^2 g - 8\pi^2 \Delta d) = -T_2^2 g \Delta d + 4\pi^2 \Delta d^2$$

$$d_1 = \frac{4\pi^2 \Delta d^2 - T_2^2 g \Delta d}{-8\pi^2 \Delta d - (T_1^2 - T_2^2) g} \longleftarrow (d_1$$

Appendix B

Sample Calculations

SAMPLE CALCULATIONS FOR THE DETERMINATION OF LONGITUDINAL AND VERTICAL CENTRE OF GRAVITY LOCATIONS FOR THE "SNOWMOBILE ONLY" LOAD CASE

LONGITUDINAL DIRECTION

THE LOCATION OF THE LONGITUDINAL CENTRE OF GRAVITY BEHIND THE FRONT SUSPENSION UPRIGHT IS GIVEN BY:

$$x_{CG} = \frac{W_{RS} \times D}{W_T} \qquad \text{Eqn (1) Sect. 7.1}$$

WHERE: W_{RS} IS THE WEIGHT MEASURED BY THE REAR SCALE

D IS THE DISTANCE BETWEEN FRONT AND REAR SCALES

W_T IS THE TOTAL MEASURED WEIGHT OF THE THREE SCALES

FOR THE SNOWMOBILE ONLY LOAD CASE:

$W_{RS} = 757$ [N] $\qquad W_T = 2323$ [N]

$D = 210.8$ [cm]

$$x_{CG} = \frac{757\,[N] \times 210.8\,[cm]}{2323\,[N]}$$

$$x_{CG} = 68.7\,[cm]$$

VERTICAL DIRECTION

THE DISTANCE FROM THE LOWER PIVOT OF THE PENDULUM TO THE PENDULUM CENTRE ... IS GIVEN BY:

$$l_{IP} = \frac{4\pi^2 \Delta d^2 - T_2^2\, a\, \Delta d}{-8\pi^2 \Delta d - (T_1^2 - T_2^2)\, g} \qquad \text{eqn (4) Sect. 7.1}$$

FOR THE "SNOWMOBILE ONLY" LOAD CASE :

$\Delta d = 53.4\ [cm] \qquad T_1 = 2.872\ [s] \qquad T_2 = 3.238\ [s]$

$g = 981\ [cm/s^2]$

$\therefore$

$$d_{1,p} = \frac{4\pi^2 \times 53.4^2\,[cm]^2 - 3.238^2\,[s]^2 \times 981\,[cm/s^2] \times 53.4\,[cm]}{-8\pi^2 \times 53.4\,[cm] - (2.872^2\,[s]^2 - 3.238^2\,[s]^2)\,981\,[cm/s^2]}$$

$$\underline{d_{1,p} = 215.9\ [cm]} \longleftarrow (d_{1,p})$$

THE DISTANCES OF THE CENTRES OF GRAVITY OF THE PENDULUM, SNOWMOBILE AND CRADLE SYSTEM ARE RELATED BY:

$$W_p d_{1,p} = W_s d_{1,s} + W_c d_{1,c} \qquad \text{Eqn (5) Sect 7.1}$$

FOR THE "SNOWMOBILE ONLY" LOAD CASE :

$d_{1,p} = 215.9\ [cm] \qquad W_p = 2613\ [N]$

$d_{1,s} = \ ?\ [cm] \qquad W_s = 2323\ [N]$

$d_{1,c} = 233.0\ [cm] \qquad W_c = 290.4\ [N]$

REARRANGING Eqn (5) TO SOLVE FOR $d_{1,s}$:

$$d_{1,s} = \frac{W_p d_{1,p} - W_c d_{1,c}}{W_s}$$

$$= \frac{2613\,[N] \times 215.9\,[cm] - 290.4\,[N] \times 233.0\,[cm]}{2323\,[N]}$$

$$\underline{d_{1,s} = 213.7\ [cm]} \longleftarrow (d_{1,s})$$

TO OBTAIN THE DISTANCE OF THE SNOWMOBILE CENTRE OF GRAVITY ABOVE THE GROUND (Z_{CG}), SUBTRACT $d_{1,S}$ FROM THE DISTANCE FROM PIVOT 1 TO THE TOP SURFACE OF THE PLATFORM (232.4 cm)

$$Z_{CG} = 232.4\ [cm] - d_{1,S}$$

$$= 232.4\ [cm] - 213.7\ [cm]$$

$$\underline{Z_{CG} = 18.7\ [cm]}$$

(Z_{CG}

CALCULATION OF THE REQUIRED FLOATATION BAG VOLUME

THE MAXIMUM ALLOWABLE FLOATED WEIGHT OF THE SNOWMOBILE FLOATATION SYSTEM IS GIVEN BY :

$$W = 0.75\,D$$

WHERE, W IS THE FLOATED WEIGHT IN [N]
D IS EQUAL TO 9.79 V
AND V IS THE TOTAL VOLUME OF FLOATATION BAGS IN [L]

REARRANGING FOR V :

$$V = \frac{W}{0.75(9.79)\ [N/L]}$$

THE DESIGN FLOATED WEIGHT OF THE SYSTEM IS :

$$W = 3770\ [N]$$

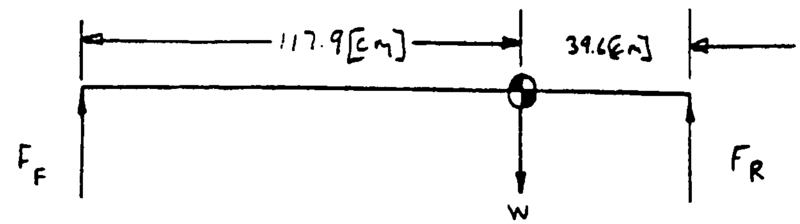
SOLVING :

$$V_{BAG} = \frac{3770\ [N]}{0.75\ (9.79)}$$

$$V_{BAG} = 513\ [L] \longleftarrow (V)$$

A) CALCULATION OF FRONT AND REAR FLOATATION BAG VOLUMES

USING THE C of G FOR THE SINGLE RIDER LOAD CASE AND THE APPROXIMATE MOUNTING POSITIONS OF THE FRONT AND REAR FLOATATION BAGS, A F.B.D OF THE SNOWMOBILE IS :



FROM A BALANCE OF MOMENTS ABOUT ⊕, :

$$\frac{F_R}{F_F} = \frac{117.9}{39.6} \quad \text{OR} \quad F_R = 3\,F_F$$

HENCE, THE FRONT AND REAR VOLUMES ARE RELATED BY

$$V_R = 3\,V_F$$

THE TOTAL REQUIRED VOLUME IS 500L

$$V_F + V_R = 500\ [L]$$

$$V_F + 3V_F = 4V_F = 500\ [L]$$

$$V_F = \frac{500}{4}\ [L]$$

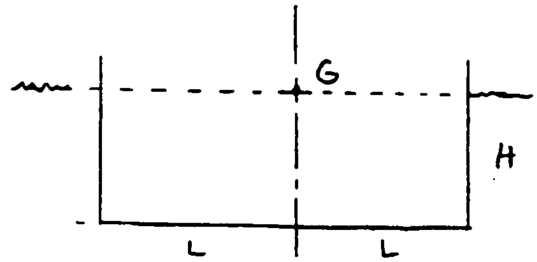
$$\underline{V_F = 125\ [L]}$$ (V_F

$$V_R = 3 \times 125\ [L]$$

$$\underline{V_R = 375\ [L]}$$ (V

B) **CALCULATION OF SNOWMOBILE METACENTRIC HEIGHT**

FOLLOWING THE PROCEDURE OF WHITE [..] TO CALCULATE THE METACENTRIC HEIGHT FOR THE CROSS SECTION GIVEN BY



THE RELATIONSHIP IS OBTAINED :

$$\overline{MG} = \frac{L^2}{3H} - \frac{H}{2}$$

FOR $L = 89$ [cm] & $H = 38$ [cm]

$$\overline{MB} = \frac{89^2}{3(38)} - \frac{38}{2}$$

$$\overline{MB} = 50.5 \text{ [cm]} \longleftarrow \overline{M}$$

CALCULATION OF REQUIRED MASS OF CO_2 GAS TO INFLATE 500L FLOATATION BAGS TO 2 psig @ -40°C :

$$2\,[psig] = 16.696\,[psia] \times \frac{6894.65\,[Pa]}{1.0\,[psia]}$$

$$2\,[psig] = 115113\,[Pa]$$

CONVERT TO kp/cm^3

$$115113\,[Pa] \times \frac{1\,[kp/cm^3]}{98066.5\,[Pa]} = 1.17\ kp/cm^3$$

FROM CHART 11 IN [4]

@ T = -40°C + P = 1.17 kp/cm^3

$$v \approx 420\,[L/kg]$$

$$M_{CO_2} = \frac{V}{v} = \frac{500\,[L]}{420\,[L/kg]}$$

$$M_{CO_2} = 1.2\,[kg]$$ ← (M

CALCULATION OF CANISTER VOLUME TO CONTAIN 1.2 kg OF CO_2 @ 30°C + 1700 psia

$$1700\,[psia] \times \frac{6894.65\,[Pa]}{[psia]} \times \frac{[kp/cm^3]}{98066.5\,[Pa]} = 120\,[kp/cm^3]$$

FROM CHART 11 IN [6]

@ $T = 30°C$ + $P = 120\,[kp/cm^2]$

$v_{CO_2} < 1.5\,[L/kg]$

So,

$$V_{canister} = v_{CO_2} \times M_{CO_2}$$

$$= 1.5\,[L/kg] \times 1.2\,[kg]$$

$$V_{canister} = 1.8\,[L]$$

(V_{can}

THE INFLATION TIME OF THE SNOWMOBILE FLOATATION SYSTEM CAN BE APPROXIMATED BY [illegible] A [illegible] TIME [illegible] A CO_2 CANISTER

ASSUMPTIONS :

1. THE STAGNATION PRESSURE OF THE CO_2 IN THE CANISTER IS INITIALLY AT 12,400 kPa AND [illegible] DECREASES DURING THE BLOWDOWN [illegible]
2. THE CO_2 BEHAVES AS AN IDEAL GAS
3. THE STAGNATION TEMPERATURE OF THE CO_2 GAS IS INITIALLY AT 0°C AND REMAINS CONSTANT DURING THE BLOWDOWN PROCESS.
4. THE NOZZLE EXIT PRESSURE IS 129 kPa absolute

CALCULATIONS :

FOR CO_2, THE SPECIFIC HEAT RATIO IS :

$\gamma = 1.30$ TABLE A.4 [1]

AT THE SONIC POINT :

$$\frac{p^*}{p_0} = \left(\frac{2}{\gamma+1}\right)^{\gamma/(\gamma-1)} = \left(\frac{2}{1.3+1}\right)^{1.3/(1.3-1)} = \underline{0.5457} \longleftarrow \frac{p^*}{p_0}$$

FOR CHOKED FLOW, THE MINIMUM P_0 IS

$$p_{0_{min}} \geq \frac{p^*}{0.5457} = \frac{129\ [kPa]}{0.5457} = \underline{236.4\ kPa} \longleftarrow p_0$$

THE MAXIMUM MASS FLOW RATE IS :

$$\dot{m}_{max} = \gamma^{1/2}\left(\frac{2}{\gamma+1}\right)^{(1/2)(\gamma+1)/(\gamma-1)} A^* p_0 (RT_0)^{1/2} \quad \text{eqn 9.46 [1]}$$

$$\dot{m}_{max} = 0.6673 \frac{p_0 A^*}{(RT_0)^{1/2}}$$

THE MEASURED NOZZLE DIAMETER FOR THE CO_2 CANISTER IS 6.35 mm

THE NOZZLE AREA IS:

$$A^* = \frac{\pi D^2}{4} = \frac{\pi (0.00635)^2}{4} = \underline{3.167 \times 10^{-5} [m^2]}$$ ← (A*

THE GAS CONSTANT FOR CO_2 is

$R = 189 \; [m^2/s^2 \cdot K]$ TABLE A.4 [1]

THE ASSUMED CONSTANT STAGNATION TEMPERATURE IS

$T_o = 0°C = 273 \; K$

THE INITIAL STAGNATION AT THE START OF THE BLOWDOWN PROCESS IS GIVEN AS:

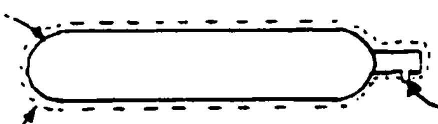
$P_o = 12{,}400 \; [kPa]$ absolute pressure

SO THE MAXIMUM MASS FLOW RATE AT THE START OF THE BLOWDOWN PROCESS IS:

$$\dot{m}_{max} = \frac{[illegible] \times 12400000 \; [N/m^2] \times 3.167 \times 10^{-5} [m^2]}{(189 \; [m^2/s^2 \cdot K] \times 273 \, [K])^{1/2}}$$

$$\dot{m}_{max} = \underline{1.154 \; [kg/s]}$$ ← ($\dot{m}$

TO FIND THE BLOW DOWN TIME FOR THE STAGNATION PRESSURE TO DECREASE FROM 12,400 [kPa] to 129 [kPa], PERFORM A CONTROL VOLUME ANALYSIS FOR THE CO_2 MASS.



$$\frac{d}{dt}(\rho_o V_{canister}) + \dot{m}_{exit} = 0$$

WHERE $\rho_o = \dfrac{P_o}{RT_o}$ and $\dot{m}_{crit} = \dot{m}_{max} = \dfrac{0.6672\, P_o A^*}{(R T_o)^{1/2}}$

THUS :

$$\frac{V_{canister}}{R T_o} \frac{dP_o}{dt} = -\dot{m}_{crit} = -\frac{0.6672\, P_o A^*}{(R T_o)^{1/2}}$$

$$\int \frac{dP_o}{P_o} = -\frac{0.6672\, A^* (RT_o)^{1/2}}{V_{canister}} \int dt$$

INTEGRATING,

$$P_o(t) = P_o(0) \exp\left[-\frac{.6672\, A^* (RT_o)^{1/2}}{V_{canister}}\, t\right]$$

For $V_{canister} = 1.850$ L

$$P_o(t) = 12400 \exp\left[-\frac{0.6672\,(3.167\times10^{-5})\,(189)(273)^{1/2}}{0.00185}\, t\right]$$

$$P_o(t) = 12400 \exp\left[-2.59\, t\right]$$

For $P_o(t) = P_{o\,min} = 236.4$ [kPa]

$$t = \frac{\ln(236.4/\ 12{,}400)}{-2.59}$$

$$\underline{t = 1.53\ [s]}$$

(t

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE AS FOLLOWS;

1. In a snowmobile having a body with a front end, a middle portion and a back end, top and bottom, and a flotation system integral thereto, said flotation system comprising:

a plurality of inflatable flotation means mounted at spaced locations on said snowmobile including two inflatable flotation means on opposed sides interior and underneath of said middle portion and one inflatable flotation means located interior and underneath of said front end; a compressed gas source; conduit means connecting said gas source with each of said inflatable flotation means; actuating means for releasing said compressed gas from said source to inflate said inflatable flotation means, said actuating means being integral with said source; each of said flotation means further comprising an inflatable envelope fluidly connected to said fluid passageway means; said envelope being collapsed prior to inflation, interiorly, underneath and within said body of said snowmobile enclosed by a sealed waterproof cover, continuous in nature.

2. The flotation system of claim 1 further comprising an integral puncture actuator and cannister system with conduit means connected to said cannister..

3. The flotation system of claim 2, wherein said actuator includes a manually actuable handle fluidly connected to a puncturing means.

4. The flotation system of claim 2, wherein said actuator further comprises an electrically operated explosive charge for automatic operation of said puncturing means.

5. The flotation system of claim 2 further comprising a flotation responsive switch mounted in a strategic location proximate the bottom immediately adjacent the exhaust pipe exit.

6. The flotation system of claim 1, wherein said inflatable envelope further comprises material substantially resistant to ice puncture and the like.

7. The flotation system of claim 1, wherein said system is used for saving lives in the event of said snowmobile falling through ice.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the front end of the snowmobile in one embodiment, with the housing cover for the inflatable envelope open.

Figure 2 shows the snowmobile in one embodiment floating in the water after activation of the inflatable envelope.

Figure 3 shows the snowmobile in one embodiment floating in the water with two occupants thereon.

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ABSTRACT

In a snowmobile having a body with a front end, a middle portion and a back end, top and bottom, and a flotation system integral thereto, said flotation system comprising:

a plurality of inflatable flotation means mounted at spaced locations on said snowmobile including two inflatable flotation means on opposed sides interior and underneath of said middle portion and one inflatable flotation means located interior and underneath of said front end; a compressed gas source; conduit means connecting said gas source with each of said inflatable flotation means; actuating means for releasing said compressed gas from said source to inflate said inflatable flotation means, said actuating means being integral with said source; each of said flotation means further comprising an inflatable envelope fluidly connected to said fluid passageway means, said envelope being collapsed prior to inflation, interiorly, underneath and within said body of said snowmobile enclosed by a sealed waterproof cover, continuous in nature.

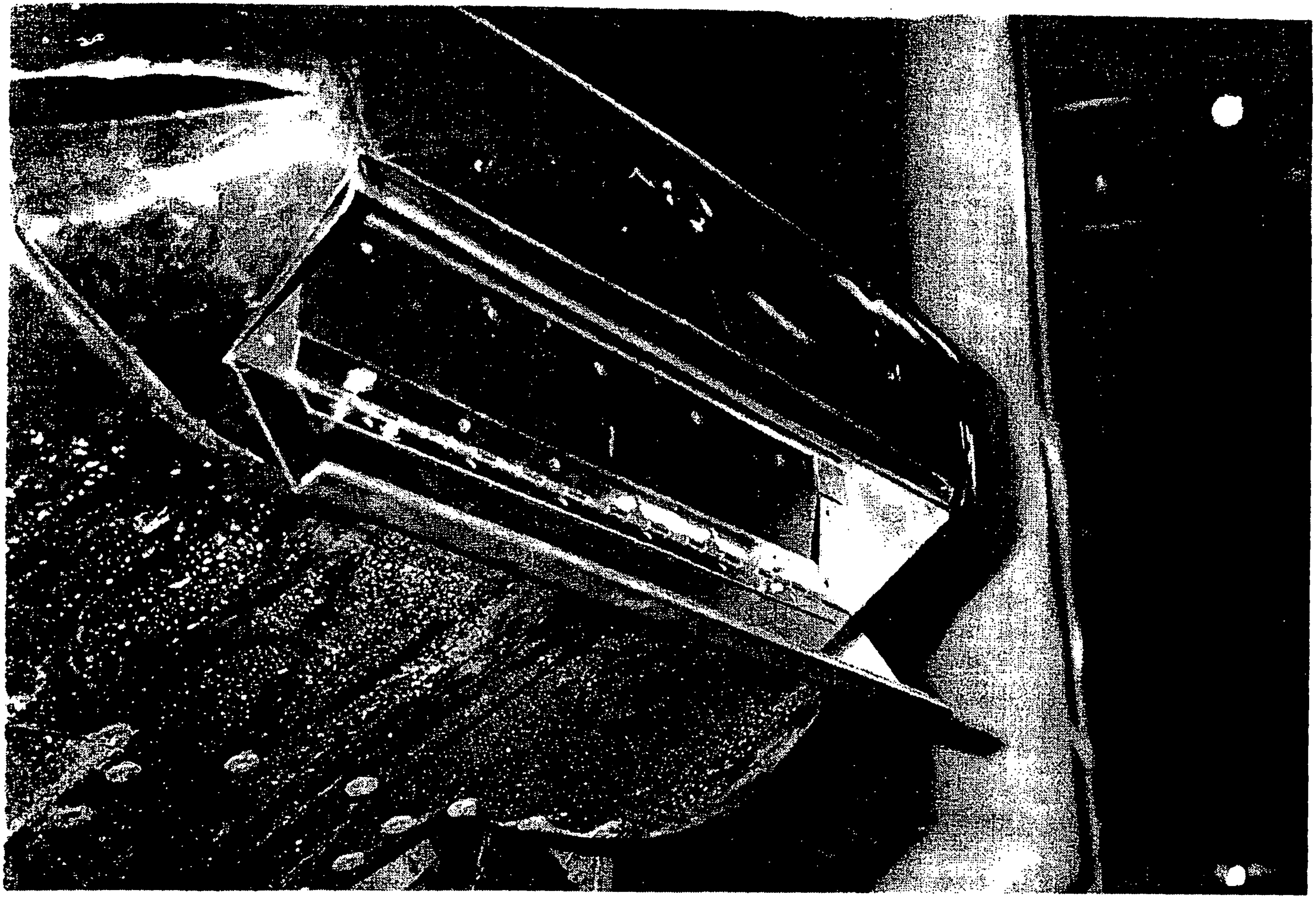

Figure 1

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Figure 2.

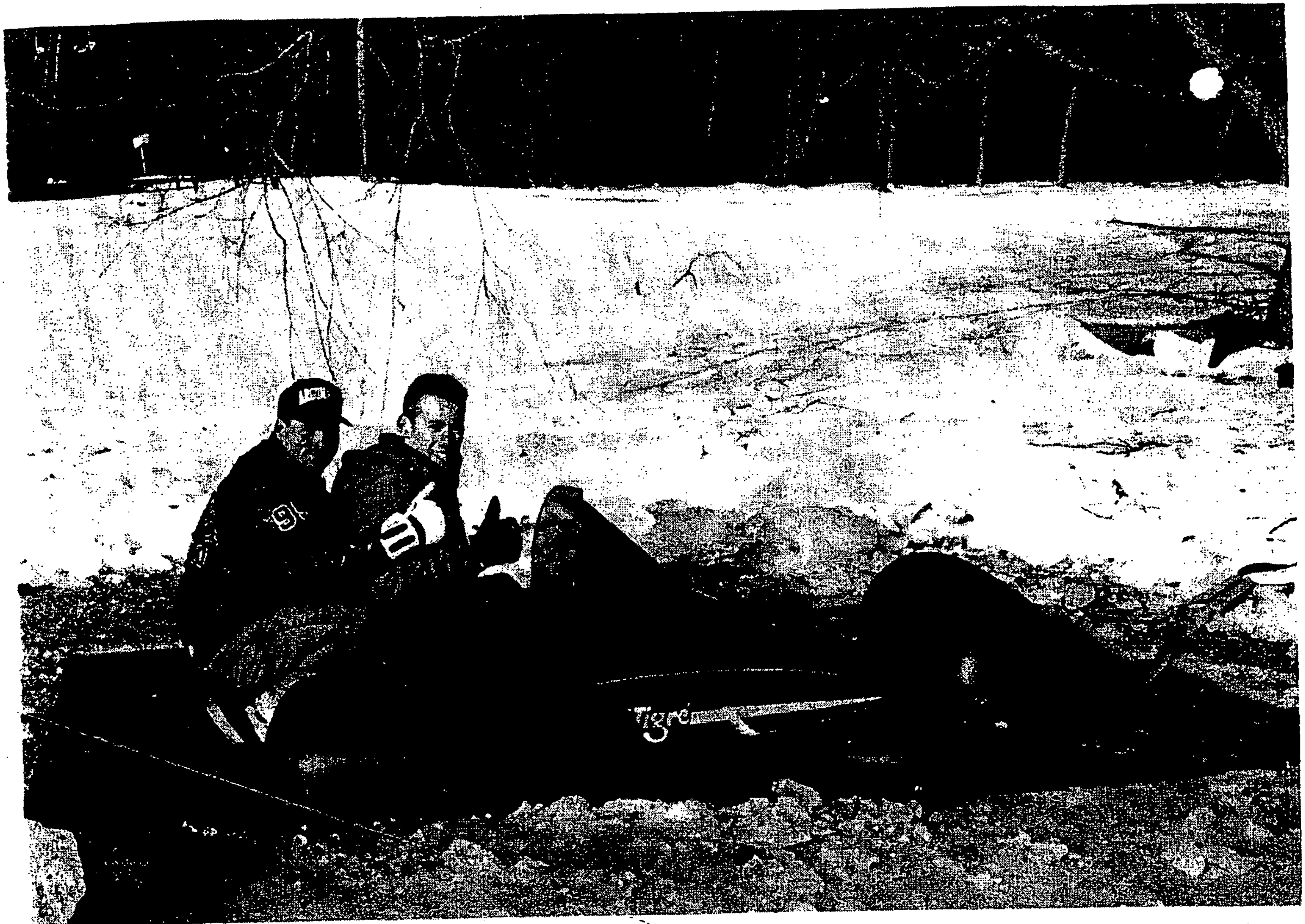

Figure 3